

# Chapter 1

## Telecommunication System Structure

A telecommunication system, in general, has the following components as shown in Fig.1.1.

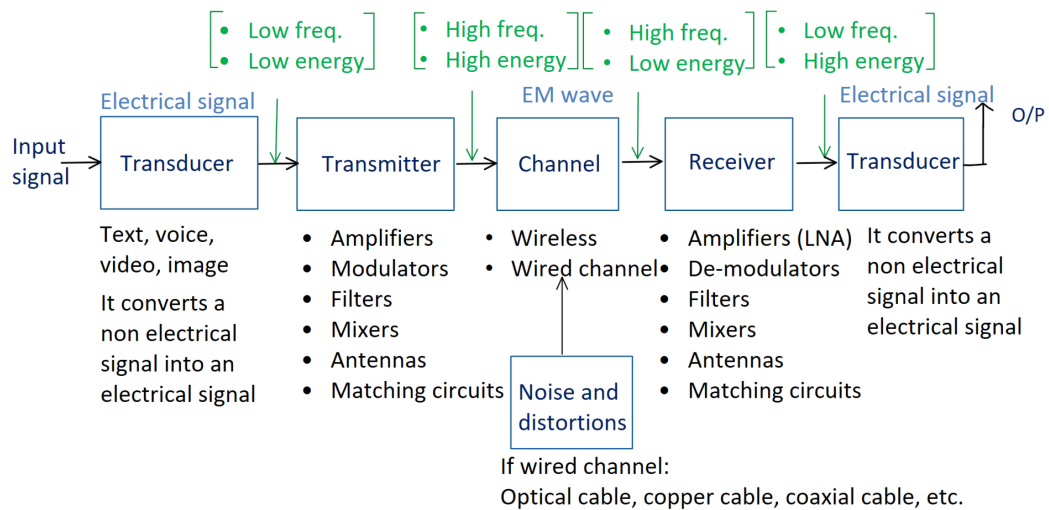


Figure 1.1 – Telecommunication system block diagram.

## 1.1 Classification of Telecommunication Systems

Telecommunication systems can be classified into two groups as shown in Fig.1.2. where simplex systems have one-way communication, and duplex systems have two-way communication.

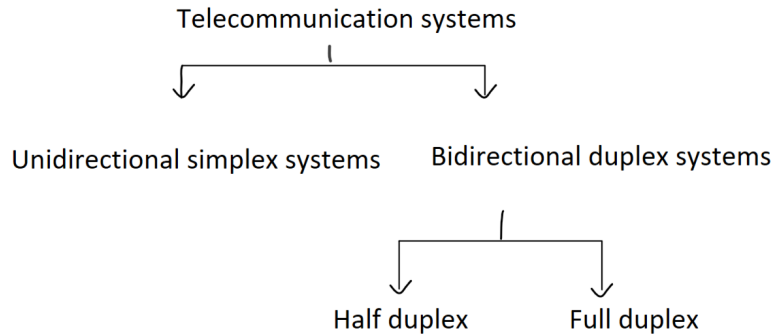


Figure 1.2 – Classification of telecommunication systems.

The following diagrams illustrate these systems. Fig.1.3 explains all these systems in drawings.

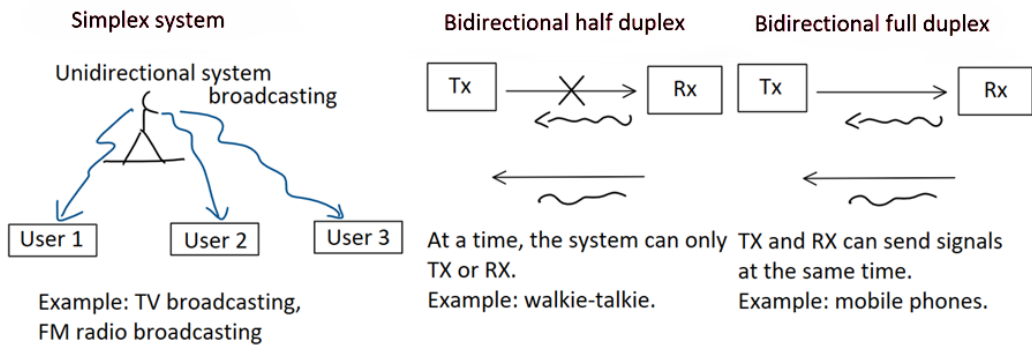


Figure 1.3 – Simplex and duplex systems.

## 1.2 Classification of Electrical Signals

Electrical signals are either voltage or current. They are grouped as:

### 1.2.1 Analog Signals

Analog signals have the following properties:

- They have infinite points.
- They are continuous in time.

An example to an analog signal is shown in Fig.1.4a.

### 1.2.2 Discrete Signals

Discrete signal have the following properties:

- They are in finite number.
- They are not continuous.
- They are obtained by sampling of analog signals.

An example to a discrete signal is shown in Fig.1.4b.

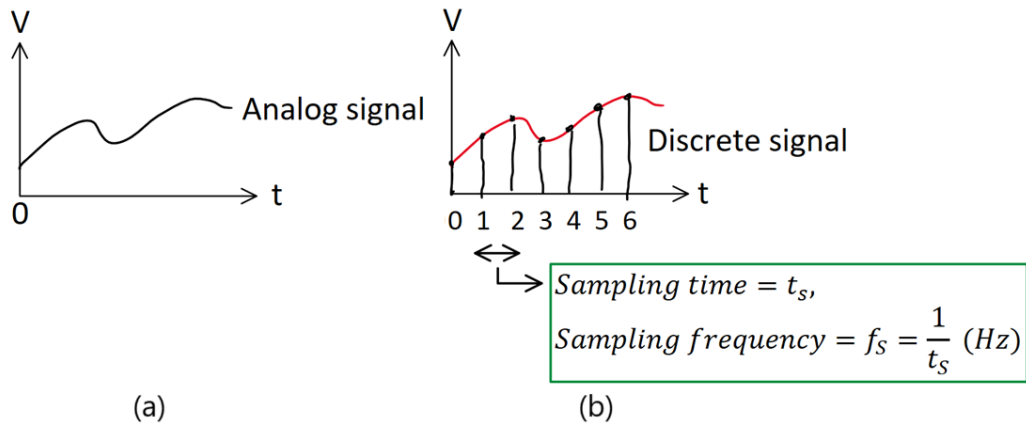


Figure 1.4 – Analog and discrete signals.

## 1.3 Signal Analysis

### 1.3.1 Time Analysis

Time analysis of signals is the plot of the signal amplitude with respect to time. Fig.1.5 shows an example time domain analysis of sine voltage signals.

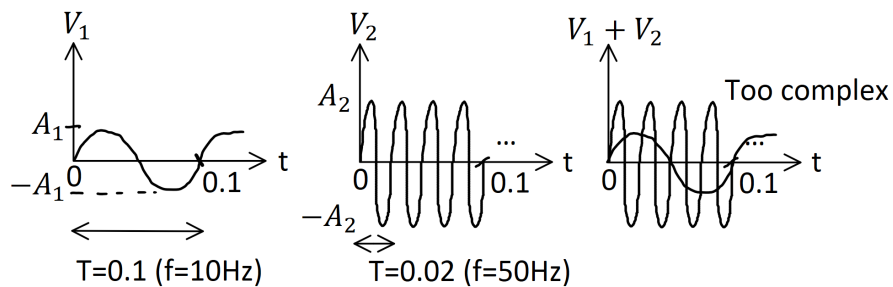


Figure 1.5 – Time analysis example.

Advantages of time analysis are:

- Phase information is available.

Disadvantages of time analysis are:

- Too complex, especially if the number of signals increase.

### 1.3.2 Frequency Analysis (Spectrum)

Frequency analysis of signals is the plot of the signal amplitude with respect to frequency. Fig.1.6 shows an example frequency domain analysis of the same sine signals given in the time analysis.

Frequency analysis is obtained by Fourier transform, Laplace transform or Z-transform (for discrete signals).

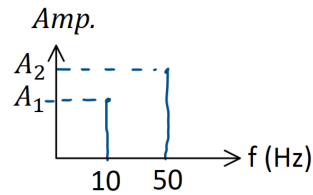


Figure 1.6 – Frequency analysis of the signals in the previous example.

Advantages of frequency analysis are:

- Simple to observe different frequency signals (less complexity).

Disadvantages of frequency analysis are:

- It does not have the phase information.

Also, it should be noted that the amplitude values are usually given in decibel with respect to 1W. For example, a signal with a power amplitude  $A = 0.001 W = 1 mW$  is equal to  $A_{dB} = 10 \log_{10} \frac{A}{1W} = 10 \log_{10} 10^{-3} = -30 dB$ .

## 1.4 Gnu Radio Companion (GNC)

Gnu radio companion (GNC) is a free license software to analyze and design signals for communication systems. It can be downloaded for Windows at the web page "<https://github.com/ryanvolz/radioconda>".

In this web site, you have to download the file "radioconda-Windows-x86\_64.exe" in the download section and install the program.

Since, computer programs can not compute infinite points, GNC uses discrete signals to operate. Thus, we need to use samples of a signal to use Gnu radio.

## 1.5 Sampling Theorem

Sampling means taking samples from an analog signal at constant time intervals ( $t_s$ =sampling time). Thus, sampling frequency (sampling rate) is defined as

$$f_s = \frac{1}{t_s} \quad (\text{Hz}). \quad (1.1)$$

Fig.7 illustrates sampling of an analog signal at sampling frequency  $f_s$ .

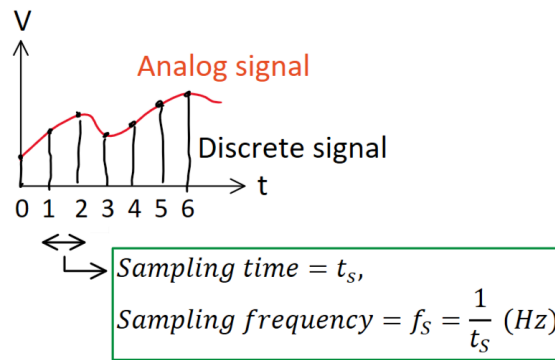


Figure 1.7 – Sampling of a sinusoidal analog signal.

If we want to re-construct the analog signal from its samples (the discrete signal), it is apparent that increased sampling rate would yield more accurate re-construction.

The minimum sampling rate in order to re-construct the signal from its samples is called the "Nyquist rate", and is given as

$$f_N = 2f_M, \quad (1.2)$$

where  $f_M$  is the highest frequency component of the analog signal.

### 1.5.1 Example

Use GNC to observe the samples of a cosine signal

$$f(t) = \cos(2\pi 1000t).$$

Keep the sampling rate at 32 kHz, and change the signal frequency  $f_M \in [1, 20]$  kHz using a QT GUI range block. Use time analysis and frequency analysis together to observe the sampled signal. Answer the following questions:

- What happens when  $f_M < f_N$ ? Draw the signal.
- What happens when  $f_M = f_N$ ? Draw the signal.
- What happens when  $f_M > f_N$ ? Draw the signal.

**Answer:**

The GNC schematic is shown in Fig.1.8. All blocks are "float" type.

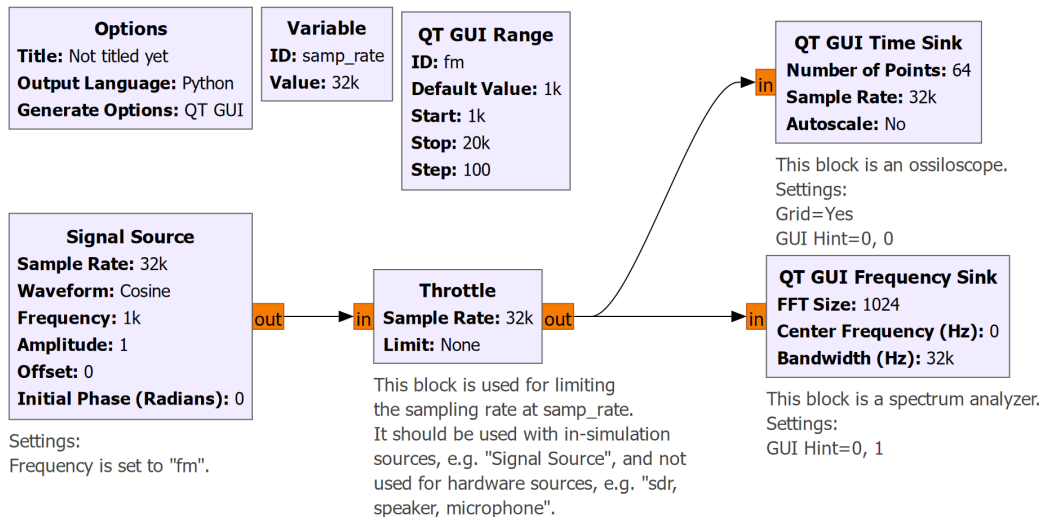


Figure 1.8 – GNC schematic design for Example 1.5.1.

Fig.1.9 shows the results for all three cases, where for  $f_M < f_N = 16$  kHz, the signal is distorted as  $f_M$  approaches  $f_N = 16$  kHz. For  $f_M = f_N = 16$  kHz,

the signal is distorted but re-constructed. For  $f_M > f_N = 16 \text{ kHz}$ , the signal is lost, the frequency analysis gives incorrect results (Aliasing).

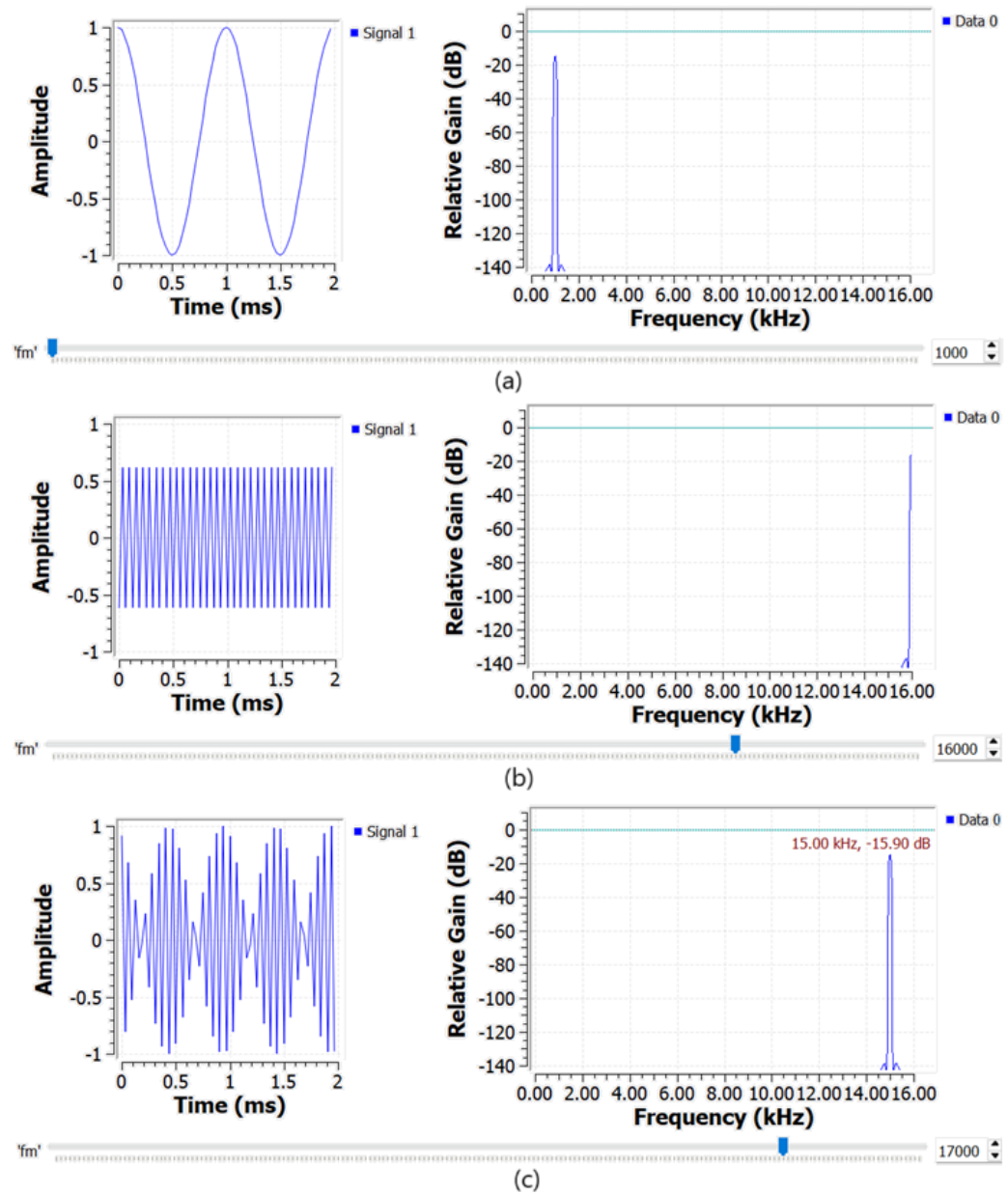


Figure 1.9 – GNC results for Example 1.5.1.

## 1.6 Audio Signals

Usually, audio signals can be obtained by a microphone. In GNC, "Audio source" block is the microphone built inside your computer. The audio signal has the following properties:

- It has a 0-20 kHz bandwidth.
- The amplitude of the audio signal determines the volume.
- The frequency of the audio signal determines the meaning of the sound.
- A single frequency sine or cosine signal is called "Tone".

### 1.6.1 Example

Use GNC to generate three different audio signals:

- a. A tone whose frequency is varied between  $f \in [0, 20]$  kHz.
- b. A microphone for user's voice.
- c. A music wave file sampled at 32 kHz.

Display these signals in time and frequency domains. Also, use a speaker to listen the corresponding audio signal. Up to which frequency, is the tone audible? Also, find the bandwidth of the voice and music signals?

#### **Answer:**

For the tone, use the "Signal Source" block. For the microphone, use the "Audio Source" block, and for the music, use the "Wave File Source" block.

At the input, you must use a "Selector" block to select one of these three audio inputs. "QT GUI Chooser" must be combined.

At the output, you must use a speaker ("Audio Sink" block), time and frequency domain analysis blocks.

The entire schematic design is shown in Fig.1.10.

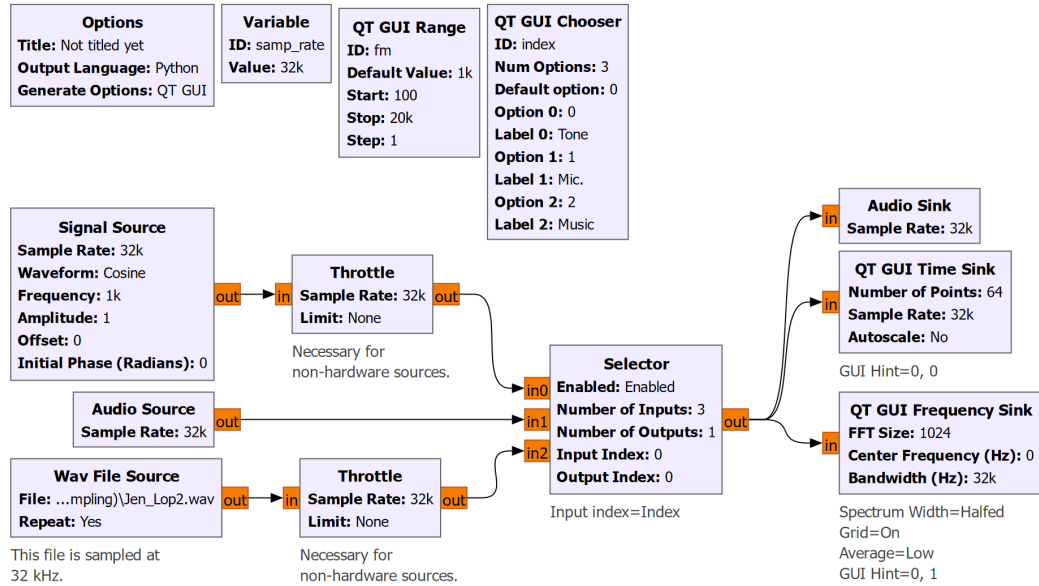


Figure 1.10 – GNC schematic page for Example 1.6.1.

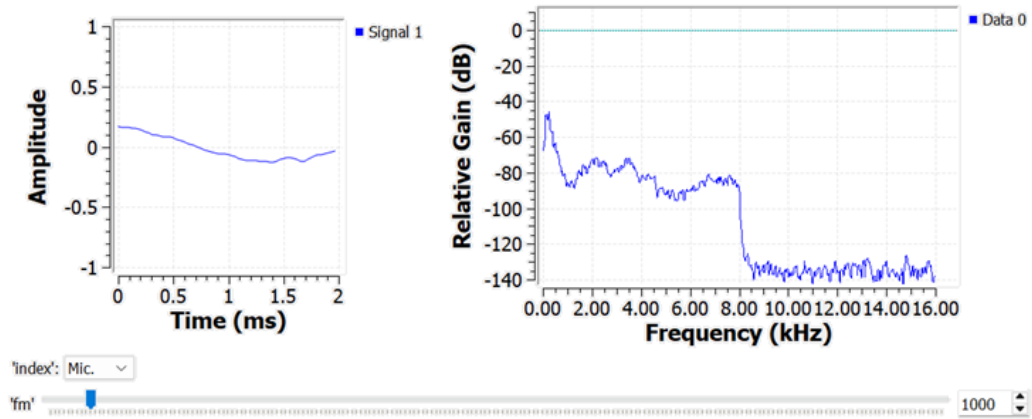


Figure 1.11 – Simulation results of Example 1.6.1.

The simulation results are shown in Fig.1.11 for the microphone selected. To answer the questions: the tone should be audible up to about 15 kHz,

the bandwidth of the voice signal is about 8 kHz, and the bandwidth of the music is about 10 kHz.